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COMMISSIONING AND USE OF THE MINIMUM IGNITION TEMPERATURE APPARATUS FOR DUST CLOUDS

K.J. Mintz and K.J. Judge

MRL 88-55(TR)

December 1988

MICROMEDIA

32 pp

COMMISSIONING AND USE OF THE MINIMUM IGNITION TEMPERATURE APPARATUS FOR DUST CLOUDS

by

K.J. Mintz* and K.J. Judge**

ABSTRACT

The minimum ignition temperature (MIT) is one of the basic parameters used for assessing the explosion hazards of dusts. The Godbert-Greenwald furnace is the standard apparatus for this measurement. The version of the apparatus now used in this laboratory is described in detail, and a procedure for routine testing is provided. The various parameters that may affect the measurement were investigated, using lycopodium, cornstarch, Pittsburgh coal and pyrite dusts as reference materials.

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*Research Scientist, ** Technologist, Canadian Explosive Atmospheres Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa

KEYWORDS: dust explosions, minimum ignition temperature

COMMANDE ET UTILISATION D'UN APPAREIL A TEMPERATURE D'ALLUMAGE MINIMALE POUR DETERMINER LES RISQUES D'EXPLOSION DES NUAGES DE POUSSIERE

par

K.J. Mintz* et K.J. Judge**

RESUME

La température d'allumage minimale est l'un des paramètres de base utilisé pour évaluer les risques d'explosions de poussières. Pour prendre ces mesures, on utilise habituellement le four Godbert-Greenwald. Une description complète du prototype modifié de cet appareil qui est maintenant utilisé dans ce laboratoire est présentée de même qu'une méthode d'essai courant. On a étudié les divers paramètres qui peuvent affecter les mesures au moyen de lycopode, de fécule de maïs, de poussières de charbon de Pittsburgh et de pyrite, à titre de matériaux de référence.

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*Chercheur scientifique, **Technicien, Laboratoire canadien de recherche sur les atmosphères explosives, Laboratoire de recherche minière, CANMET, Energie, Mines et Ressources Canada, Ottawa

MOTS CLE: explosions de poussière; température d'allumage minimale.

TABLE OF CONTENTS

Page

ABSTRACT..... i

RESUME..... ii

INTRODUCTION..... 1

APPARATUS..... 2

RESULTS AND DISCUSSION

Lycopodium..... 5

Cornstarch..... 8

Pittsburgh coal dust..... 8

Sulphide ore dusts..... 9

CONCLUSIONS..... 10

ACKNOWLEDGEMENT..... 11

REFERENCES..... 12

TABLES

No.

1. Effect of mass on the ignition probability..... 14

2. Effect of solenoid open time on the ignition probability..... 14

3. Effect of pressure on the ignition probability..... 15

4. Ignition probability of cornstarch dust..... 15

5. Ignition probability of Pittsburgh standard coal dust..... 16

FIGURES

No.		Page
1.	Schematic diagram of MIT apparatus	17
2.	Effect of dispersion air and ignitions on the furnace temperature	18
3.	Circuit diagram of clock and air-on time control	19
4.	Timer circuit diagram	20
5.	Power supplies in control box	21

APPENDICES

A.	Procedure for carrying out MIT tests	22
B.	Parts list for the control box for the MIT apparatus	26

INTRODUCTION

The minimum ignition temperature (MIT) of dust clouds is one of the basic parameters of dust explosions. It is defined as the lowest temperature at which ignition of a dust cloud of a given material can occur. The standard apparatus used for this measurement is the Godbert-Greenwald furnace (1). Basically, the apparatus consists of a tubular furnace which is open at the bottom. An air pulse travels through a chamber in which dust has been placed, picks up the dust, and brings it through a tube into the top of the furnace. Flames emitting from the bottom of the furnace are indicative of the furnace temperature being above the MIT. There are slight differences between the version used in the U.S.A. and that used in the U.K. (2). The use of the Godbert-Greenwald furnace is quite widespread; MRL has been using it for a number of years (3).

More recently, the USBM has developed a 1.2-L closed furnace with an improved dust dispersion method and a longer exposure time (4). This furnace has yielded lower values for the MIT than the Godbert-Greenwald; the authors have recommended that the 1.2-L furnace replace the Godbert-Greenwald apparatus. Although the 1.2-L is probably more scientifically sound than the Godbert-Greenwald apparatus, the latter is still more widely accepted. Therefore, it is essential that CEAL have a functioning apparatus. The purpose of this report is to fully describe the equipment, record the improvements that have been made, determine how the various experimental variables can affect the results and set a procedure to be followed for routine testing.

APPARATUS

Preliminary tests with the existing apparatus indicated that much of the dust sample placed in the sample holder remained there after the test. Therefore, the air system was modified in four ways: (a) the air pressure chamber was situated in-line with the inlet and outlet, (b) the volume of tubing was minimized, (c) a check valve was installed, and (d) a new solenoid valve was installed. By these means, the pulse of air became sharper and was thus able to entrain virtually all of the dust that is placed in the sample holder.

A schematic diagram of the apparatus as it currently exists is shown in Fig 1. The temperature controller is a Thermoelectric Corporation Model 400, which is a proportioning type with digital set-point. This controller does not produce precisely the set temperature: for 200° set-point, it stabilizes at 160°C, for 300°C, it stabilizes at 273°C, for 400°C, it stabilizes at 385°C, for 700°C, it stabilizes at 694°C. Therefore, the actual temperature should be used for the MIT, rather than the set-point temperature.

Godbert and Greenwald in their original study (1) measured the distribution of temperature in their furnace. In the central part of the furnace, which is the hottest part, the temperature on the axis was about 5°C lower than on the wall, when the furnace temperature was at 720°C. The temperature inside our furnace was not as uniform: The difference varied from about 20°C at 300°C to about 10°C at 700°C. When the dust dispersion system was removed from the top of the furnace and replaced with a glass wool plug, the temperature difference decreased to 3°C at 300°C. Hence, the temperature differential is caused by convection currents, which would affect

the centre more than the air near the walls, because the latter is continuously absorbing more heat radiation from the heated walls. The heater is on more continuously at higher temperatures, and thus provides more uniform heating and less temperature difference.

When the lid of the sample holder is opened, the temperature of the furnace, particularly at the centre, starts dropping, because a strong convection current can start. Therefore, the lid should be opened for as brief a time as possible, just long enough time to add the sample, and the furnace allowed to recover for at least 30 s before testing.

According to Field (2), the current U.K. version uses a thermocouple impinged on the wall for controlling the temperature. The U.S. (5) uses a thermocouple projecting 1/32" from the wall for control. For our work, a 1/8" diameter thermocouple positioned about 1/8" from the wall was used for this purpose. A second thermocouple, 1/16" diameter (for faster response), was placed on the axis as a check. As noted above, these thermocouples yield different temperatures; it is necessary to decide which is more appropriate to use for determining the MIT. For an explosible dust cloud, the critical factor that could cause an ignition is the hottest surface in contact with the dust. Hence, the wall thermocouple should be used.

When a test is conducted by blowing dust-laden air into the furnace, the temperature of the furnace decreases because this air is initially at room temperature. A test was carried out without a dust sample to determine the magnitude of this effect. As expected, the temperature drop is greater at the centre than near the walls (see Fig. 2). The furnace takes about one minute to recover to its original temperature. In principle, one could correct for this temperature change. Because the wall temperature change is fairly small and also to remain in accordance with general practice of other

laboratories using this apparatus, a correction for this effect was not made. Figure 2 also shows the temperature rise when a strong ignition of a dust cloud occurs. (The initial temperature is about 200°C above the MIT.) The time required for recovery of the initial temperature is about a minute.

A new control box was built which allows the user to accurately control the time that the solenoid valve is open. The control box contains, in addition, a timer, which starts automatically when the solenoid is opened and is stopped manually by the operator when a flame is observed. This timer provides an estimate of the delay time. Lee (12) has used a phototransistor connected to an oscilloscope to automatically measure the time of appearance of the flame. He has found that the logarithm of the delay time is a linear function of the reciprocal of the absolute temperature, i.e. the reaction obeys the Arrhenius Law, and therefore the activation energy of the ignition can be determined.

The control box is essentially a stand-alone timer, a controlled switched ac outlet and an "event timer". The controls consist of a run switch, a three digit thumbwheel switch (allowing millisecond control (0-999) of the ac outlet activation and on time), and "event timer" stop and reset switches.

The switched outlet electronics (Fig.3) consist of a clock (U1) a presettable counter (U2-7) and a FET output (Q1) which drives a relay. The electronics is the same as that described for the Hartmann and 20-L vessels (13) except that there is no "arc-on" or "delay" timer and that a debounce circuit is added to the run signal, since the circuit has no other form of lockout.

The debounce circuit consists of two cross coupled nor gates (U2) and the signal is fed to these through limiting resistors R6 and R8.

Resistors R7 and R9 act as pull down resistors and capacitors C4 and C5 help to remove spikes on the incoming signal from toggle switch SW1.

Operation of the system involves setting the desired air-on time in ms via the thumbwheel switch and pressing the toggle switch to the right.

The "event timer" electronics (Fig.5) consists of the above 1 ms clock, a divide by ten counter (U8) and a four digit counter (U9) with seven segment display (D2-D5).

The 1 ms "clock" signal is gated (U2-3) with a latched "run" signal (U3-2) and passed through the divide by ten counter thus generating a 0.01 s clock pulse which is sent to the "event time" counter. The resulting resolution (10 ms) is more than adequate (given the response time of the operator) and with a four digit counter allows up to 99.99 s "event timing" which is long enough for the MIT test.

The counter is left free running for continuous update of the display except when frozen by the store switch (SW3). Once stopped, the counter may be reset by pressing the reset switch (SW2) which also resets the run latch; the system is then ready for another run.

RESULTS AND DISCUSSION

Lycopodium

Lycopodium was used to evaluate the parameters of the apparatus, because it is a very homogeneous dust. Tests carried out on the apparatus before the modifications were made yielded a MIT of 560 °C. With the modifications, the MIT decreased to 460 °C, thus demonstrating the necessity for careful design of the dust dispersion apparatus. The latter value is slightly lower than Field's value of 470 °C, (2), and Jacobson's value of 480

°C (6), both carried out using Godbert-Greenwald furnaces. On the other hand, it is somewhat higher than Conti and Hertzberg's value of 435 °C (7), measured in the 1.2-L vessel. Hertzberg et al (4) have measured the variation of MIT with concentration in the 1.2-L vessel: their graph indicates that the MIT has a slight dependence on concentration, decreasing from about 460 °C at 200 g/m^3 asymptotically to about 420 °C at 1300 g/m^3. Because of the nature of the Godbert-Greenwald furnace, it is impossible to generate high concentrations of dust, therefore, it is reasonable to expect that the apparatus will yield slightly higher values of the MIT than the 1.2-L vessel.

The effect of temperature and mass of dust placed into the sample holder is shown in Table 1. Increasing the mass clearly increases the probability of ignition up to a certain point. Beyond that, it does not seem to have any significant effect. Part of the observed variation of ignition probability with mass may be a true concentration effect. However, because of the nature of the apparatus, the dust cloud formed is not homogeneous and the true concentration is probably somewhat less than the nominal. 0.1 g of dust in the MIT corresponds to a nominal concentration of about 300 g/m^3. Hertzberg's data (4) indicates a fairly rapid increase in the MIT of lycopodium when the concentration is decreased below about 150 g/m^3. Hence, our data are reasonably consistent with Hertzberg's. The optimum quantity of dust must be determined for each material; from these tests a good starting point appears to be 0.2 g. The dependence of apparent MIT on concentration is not large (except near the minimum explosible concentration); therefore, highly accurate weighing is not required; ±10% is adequate. The two sets that were carried out under the same conditions a week apart provides an indication of the reproducibility.

The effect of solenoid open time is shown in Table 2. It would appear that 150 ms is the optimum time for lycopodium. A too short open time may not entrain all the dust. A too long open time may shorten the residence time, thus not allowing thermal equilibrium between the dust cloud and the walls of the furnace to occur. If the kinetics of the dust/air explosion are such that a there is a long induction time, a shorter solenoid time may be required. The ignition probability does not appear to be a strong function of the solenoid open time.

The effect of pressure on the ignition probability is shown in Table 3. The optimum value for lycopodium appears to be about 70 kPa. Higher pressures decrease the residence time of the dust cloud in the furnace; too low pressures may not entrain all the dust. It appears that pressure does have significant effect on the ignition probability. Too high a pressure may yield a MIT substantially too high.

In the U.K., the standard procedure calls for decreasing the furnace temperature in 10°C increments until no flame is observed. The U.S. procedure is to keep reducing the temperature in 5°C increments until no flames in four successive trials occur. Our results (Tables 1 - 3) indicate that there is not a sharp cut-off between ignition and non-ignition: the temperature range between 0% and 100% probability is about 30 °C for lycopodium. Hence, the empirical minimum ignition temperature is a function of the number of trials at the temperature just below the MIT. Four or five trials is sufficient to establish the MIT for lycopodium within ±5 °C. Other, less homogeneous, dusts may require a greater number of trials.

Cornstarch

The results of testing a commercial cornstarch are shown in Table 4. The optimum conditions were at a higher pressure and shorter solenoid open time than for lycopodium. The probable cause for these differences is that the cornstarch particles tend to stick together: a higher pressure is required to separate them. A shorter solenoid open time is required with the higher pressure to produce the same residence time.

As can be seen from Table 4, drying the cornstarch lowered the MIT about 10°C. A few tests with twice the quantity of cornstarch did not yield any different results.

The rounded-off MIT value of 410°C is in the same range as other MIT values determined for cornstarch: 390 - 490°C, by Jacobson et al (6) using the Godbert-Greenwald apparatus, 403°C by Dorsett et al (5) also using the Godbert-Greenwald apparatus, and 400°C by Conti and Hertzberg (7), using the 1.2-L apparatus. Note that in this case, the 1.2-L apparatus yielded the same MIT as the Godbert-Greenwald apparatus.

Pittsburgh Standard Coal Dust

A sample received from the Bruceton Laboratory of the U.S. Bureau of Mines yielded an MIT of 620°C (see Table 4). This is slightly higher (but within our estimated experimental error) than the value of 610°C, reported in several U.S. Bureau of Mines publications (5,8,9), for tests carried out with the Godbert-Greenwald furnace. The U.S. Bureau of Mines has obtained MIT values of 540°C (7) and 560°C (4), using the 1.2-L apparatus. Feng (3) reported a very low value, 500°C, using the Godbert-Greenwald furnace.

Sulphide Ore Dusts

Unlike the other dusts tested, sulphide ore dusts do not produce flames; they produce only sparks: a shower at higher temperatures or single sparks near the limiting temperature. This phenomenon does not appear to have been reported or discussed in the literature, except a brief mention in a paper by Godbert (10), in which "a few sparks" is considered as a "non-inflammation". (This paper considered coal, not sulphides.) The U.S. Bureau of Mines (11) has measured the MIT of iron pyrites to be 420°C for particles less than 74 μm in diameter, i.e. dust that had been passed through a 200 mesh screen, but no mention is made whether a flame or just sparks were observed. The value of 420 °C is actually the lowest value obtained from several samples, which had MIT's between 420 - 470 °C. Field (2) quotes a value of 380°C, supposedly also from the same reference (11).

A sample of pure pyrite dust was prepared by Noranda Research for explosibility testing by CEAL. They wet-screened it through 150 mesh, which corresponds to particle diameters of less than 106 μm. The MIT obtained in our apparatus was 530°C, somewhat higher than the USBM values. Possibly, the larger particle size in our tests was the cause of the discrepancy; further work would have to be carried out on the effect of particle size on the MIT of sulphide ore dusts.

Pyrite, along with other sulphide ore dusts and unlike most other combustible dusts, cannot be ignited by an electrical spark in air; it requires a much higher ignition source, such as the Sobbe 5 kJ pyrotechnic ignitor. In the Godbert-Greenwald furnace, not enough concentration of energy can be transferred to the pyrite dust to be equivalent to this ignitor. Although enough energy is transferred to particles to start an exothermic reaction, the energy carried by these glowing particles is

insufficient to set off a deflagration. Similarly, in explosion tests carried out in the Hartmann and 20-L vessels, the spark discharge could not provide enough energy to ignite a dust cloud of pyrite; a more powerful ignitor (Sobbe pyrotechnic) was required.

The meaning of an MIT based on observation of sparks without a flame must be carefully considered. Conti and Hertzberg define "ignition" as "the generation of a self-sustaining deflagration or explosion" (7). Clearly, a single spark, or even a shower of sparks, does not fit that definition. On the other hand, it does indicate the presence of an exothermic reaction; the hot sparks could ignite other materials in the vicinity and, therefore, does indicate the presence of a hazard. Whether or not it is necessary to consider the "MIT" based on sparks is a matter of the hazard analysis of the particular operation.

CONCLUSIONS

The analysis of the various sources of error involved in the use of the Godbert-Greenwald furnace indicate that the accuracy achievable is of the order of ±10°C (neglecting any sample inhomogeneity). Results obtained with lycopodium, cornstarch and Pittsburgh coal dust are in acceptable agreement with those from the literature. The importance of varying the various parameters of the test for each material in order to determine the true MIT has been shown.

The 1.2-L MIT apparatus developed by the U.S. Bureau of Mines would overcome the limitations of the Godbert-Greenwald apparatus and provide more scientifically valid data. It is recommended that CEAL make such an apparatus once it has been incorporated into a standard, or, at least, has

become more widely recognized. In the meantime, the CEAL Godbert-Greenwald apparatus has been brought to a state at which reliable and reproducible data can be generated on a routine basis.

ACKNOWLEDGEMENT

The authors would like to thank Mr. J.-P. Saindon of Noranda Research Centre for preparation of the pyrite dust sample.

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Table 1. Effect of mass on the ignition probability

	Mass (g)			
Temp.(°C)	0.05	0.1	0.2	0.4
490	4/5	--	--	--
480	2/8	4/5	4/5	--
471	3/12	--	4/10	--
460 - set (a)	--	2/5	2/5	1/5
set (b)	0/10	0/5	3/10	--
450	--	--	0/5	--

Note: All tests used 70 kPa pressure and 100 ms solenoid open time. Sets (a) and (b) were carried out a week apart.

Table 2. Effect of solenoid open time on the ignition probability

	Solenoid open time (ms)			
Temp.(°C)	50	100	150	300
471	1/5	4/10	7/10	2/5
450	--	0/5	0/5	0/5

Note: All tests used 70 kPa pressure and 0.2 g sample.

Table 3. Effect of pressure on the ignition probability

	Pressure (kPa)		
Temp.(°C)	50	70	100
483	1/5	4/5	3/5
471	2/5	7/10	0/5

Note: All tests used 0.2 g sample and a solenoid open time of 150 ms.

Table 4. Ignition probability of cornstarch dust

	Pressure (kPa)					
	70		100		140	
Open time:	100 ms	150 ms	100 ms	150 ms	100 ms	150 ms
Temp.(°C)						
431	3/8*	1/4	5/5*	4/4	--	--
421	--	--	5/5*	0/4	3/4	1/4
409	--	--	2/5*	--	0/4	--
					3/4*	--
401	--	--	--	--	0/5*	--

Note: All tests used 0.2 g sample; solenoid open times were 100 or 150 ms as noted. The asterisk refers to samples that had been heated to 90°C for one hour prior to the test.

Table 5. Ignition Probability for Pittsburgh Standard Coal

	Pressure (kPa)	
Temp.(°C)	70	100
630	--	5/5
622	2/4	3/5
612	0/6	0/6

Note: All tests used 0.2 g sample; solenoid open times were 100 ms.

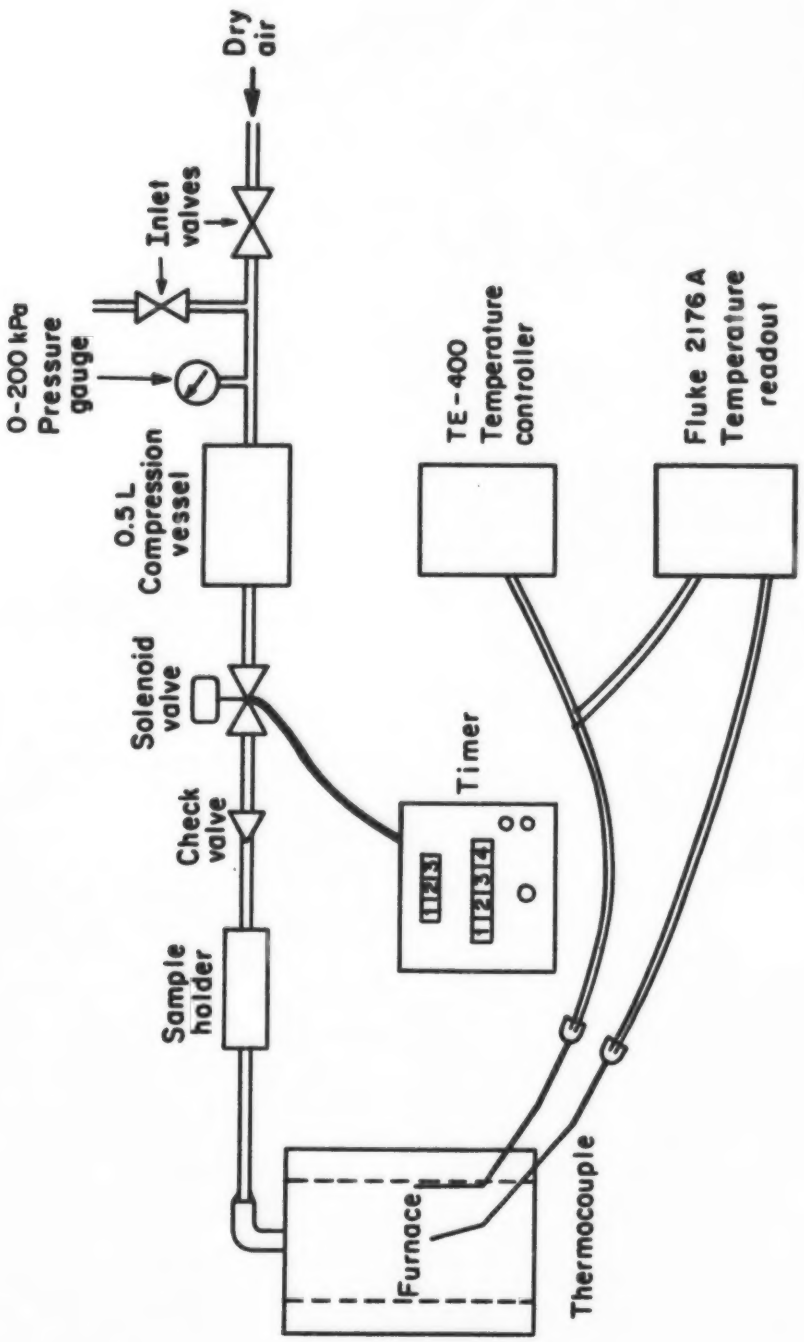

Fig. 1. Schematic diagram of MIT apparatus

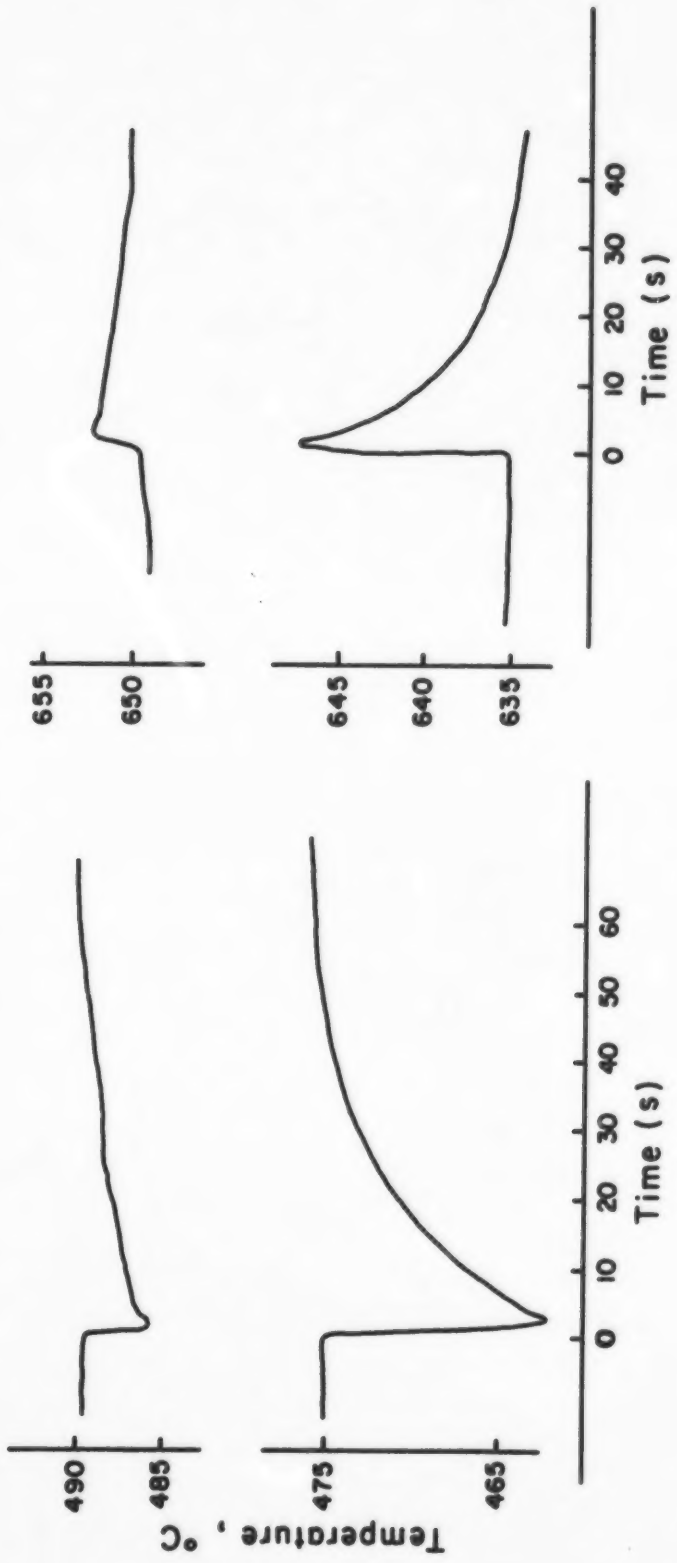

Fig. 2. Effect of dispersion air and ignitions on the furnace temperature

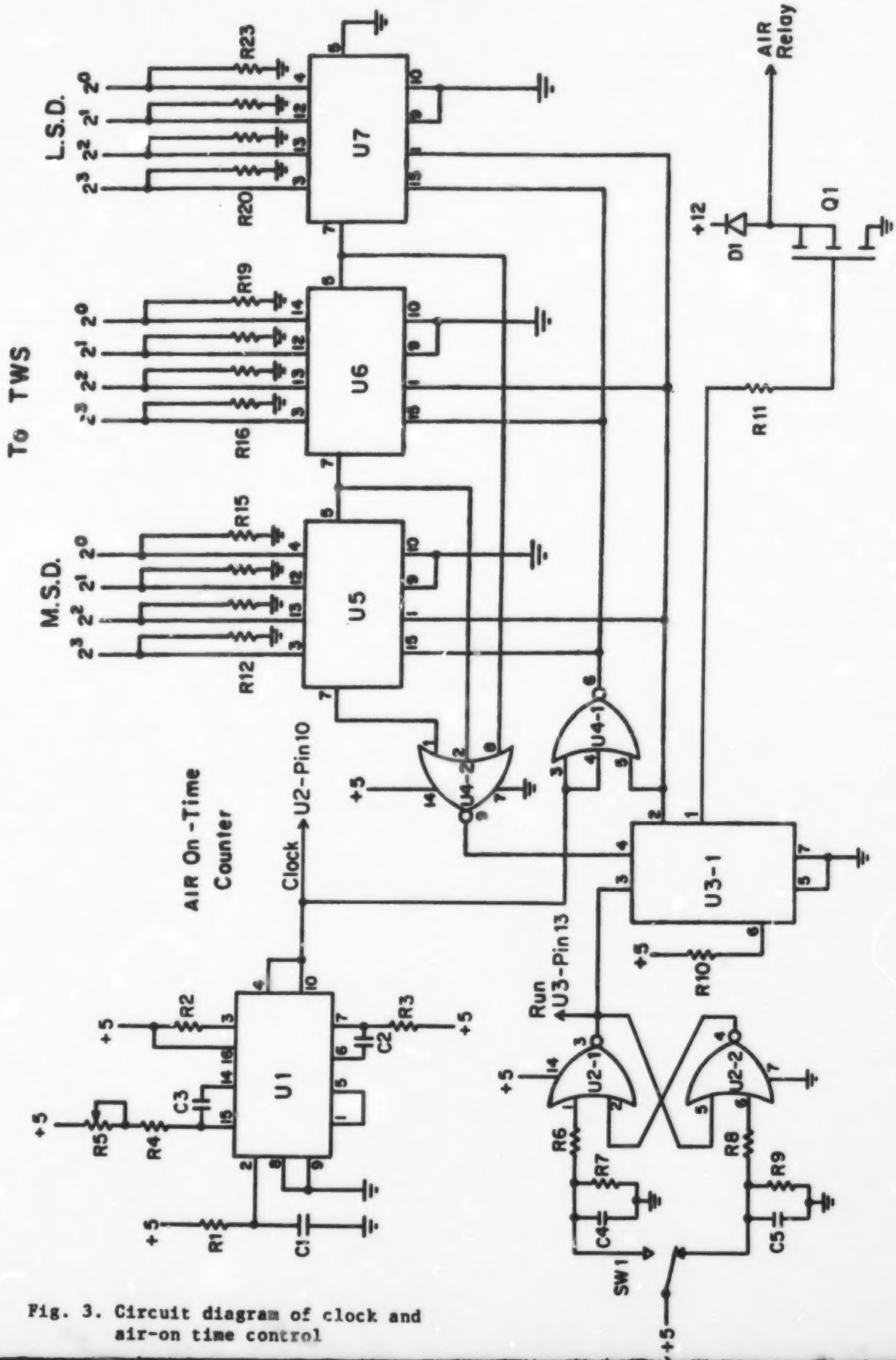

Fig. 3. Circuit diagram of clock and air-on time control

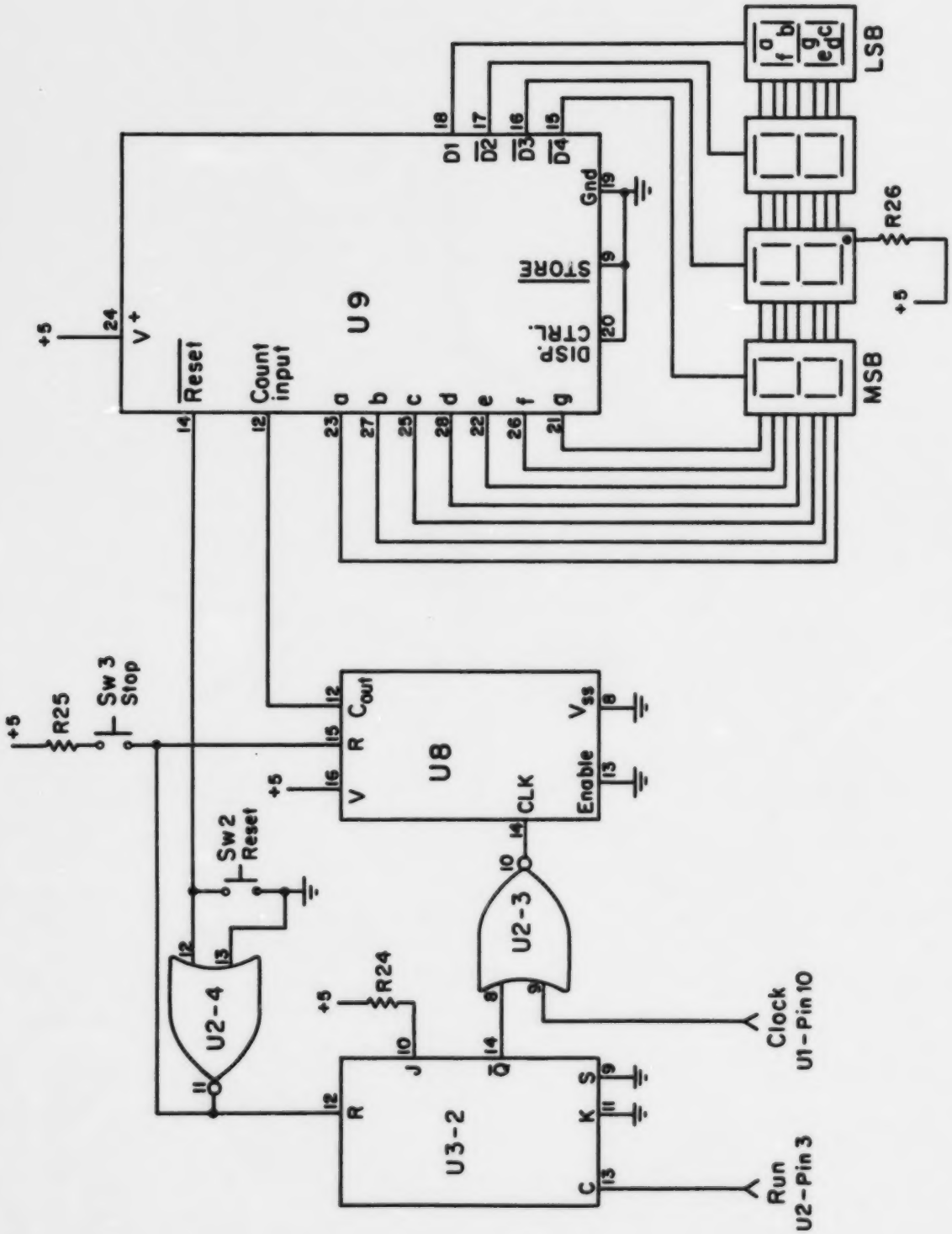

Fig.4. Timer circuit diagram

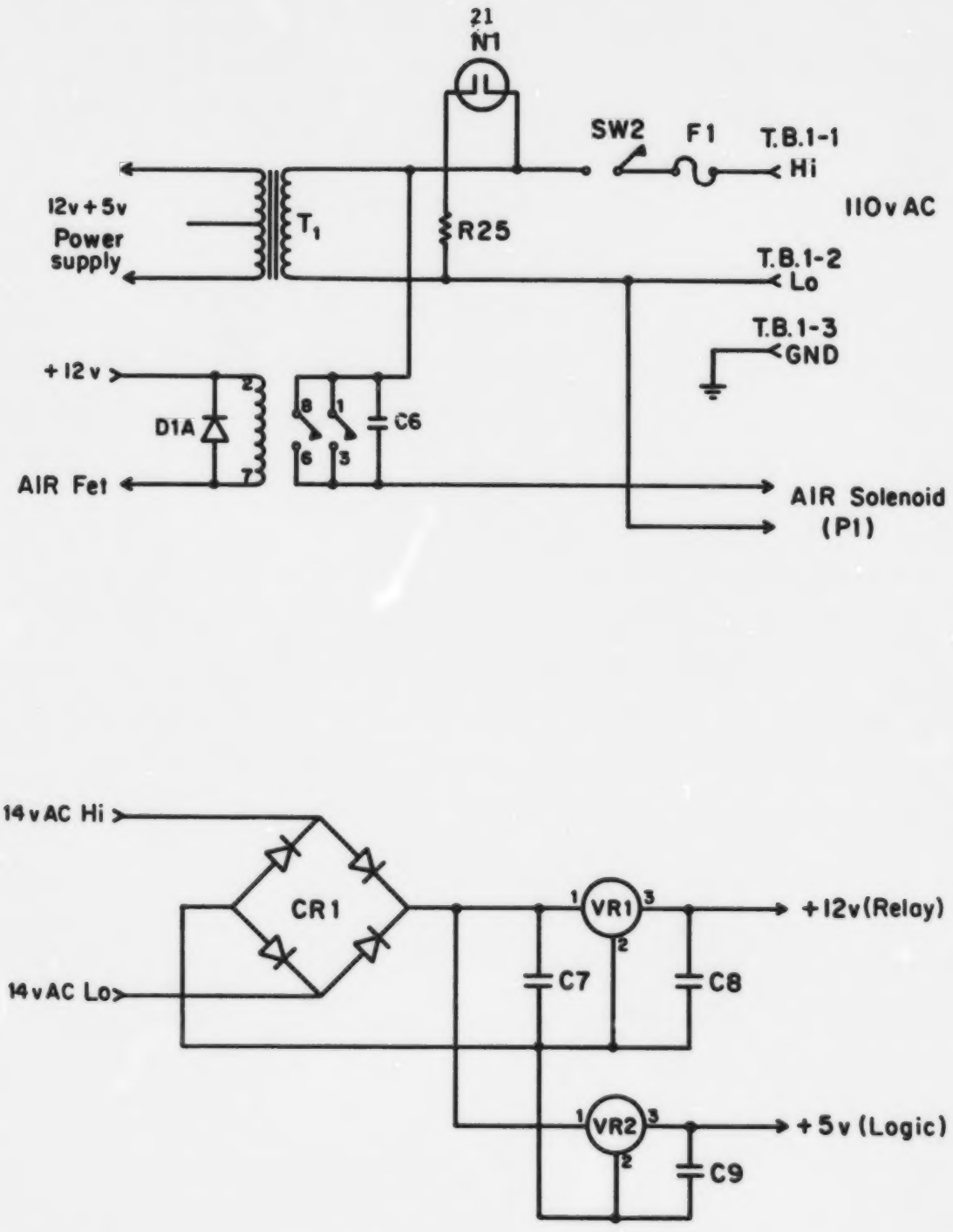

Fig. 5. Power supplies in control box

APPENDIX A

PROCEDURE FOR MINIMUM IGNITION TEMPERATURE TESTS USING THE GODBERT-GREENWALD FURNACE

1. Ensure that the apparatus is on its dedicated table and wheel it into the fume hood.
2. Lift the dust dispersion system off the top of the furnace. Check that the 1/8" diameter thermocouple is close to the wall, but not touching, and that the 1/16" diameter thermocouple is in the centre of the furnace. Lower the dust dispersion system carefully into place.
3. Check that the 1/8" diameter thermocouple is connected to the temperature controller which should also be connected to the digital temperature readout. Check that the 1/16" diameter thermocouple is connected to the temperature readout.
4. Connect the dust dispersion system to the air outlet in the fume hood using Tygon tubing. The corresponding outlet outside the fume hood should be connected to a cylinder of extra dry air. Open the cylinder valve and adjust the pressure to 160 kPa.
5. Plug in the control box and temperature readout and turn them both on. Allow 10 minutes for warm-up. Both thermocouples should read room temperature.
6. Open the dust reservoir on the apparatus and ensure that it is clean, then close it. Open the valve on the dust dispersion system to allow air to enter from the cylinder. Press the toggle switch to the right a few times to observe whether any dust is ejected from the bottom of the furnace. If so, further cleaning is required.

7. Set the desired starting temperature on the temperature controller and plug it in.
8. Prepare the dust sample. Often, samples are sieved through a 200 mesh screen. Usually, coal is dried at 105°C for 2 hours and other dusts are dried at 75°C for 24 hours. However, the requirements for each dust must be considered on an individual basis.
9. Turn on the fume hood.
10. Weigh out the sample (to ±10%). Usually, the starting point is 0.2 g, but other values may be used.
11. Open the sample holder and quickly sprinkle the dust along the length of the holder and close the holder.

    Note: When the sample holder is opened, a convection current develops which cools the air inside the furnace. To minimize errors caused by this factor, the sample holder must be opened only when inserting the sample and for as briefly as possible.
12. Open the valve to the cylinder until the pressure on the gauge is the desired starting pressure (usually 100 kPa). Close the valve.
13. Set the solenoid open time on the control box to that desired, usually 150 ms.
14. Record the temperature of the two thermocouples. Although the MIT is based solely on the wall thermocouple, the centre thermocouple should be no more than 20°C lower.
15. Turn off the room lights and press the start lever to the right. Press the stop button on the control box when a flash or sparks are emitted from the bottom of the furnace. Record that delay time, or indicate if no event occurred.
16. Lower the set temperature in minimum of 10°C intervals.

Note: The various sources of error are sufficiently large that it is useless to try to determine the MIT to better than ±10 °C.

17. When a temperature has been reached at which no events occur in four trials, vary the parameters to determine if this temperature is in fact below the MIT. The mass of dust can be doubled, the pressure can be increased or decreased by 30 kPa, and the solenoid open time can be increased or decreased by 50 ms. For each change in parameter, four trials which turn out negative must be carried out before proceeding. If any event occurs, the temperature should be decreased by 10°C and the process repeated.
18. The lowest temperature at which an event occurred is the MIT: round it to the nearest 10°C.
19. Turn off the main valve of the air cylinder, turn off and unplug all the electric equipment, turn off the fume hood, and clean up the table.
20. After the apparatus has cooled, remove the dust dispersion system, disassemble it, and clean it.

Safety Precautions:

1. Possible toxic products of combustion may be evolved: the fume hood must be on during tests.
2. Dusts may be flammable or explosible: minimize quantities used in apparatus and practice good housekeeping.
3. Some dusts may be allergens for some people: if necessary, use vinyl gloves.
4. The furnace gets very hot: do not touch.
5. Wear safety glasses during tests.

Note: Self-explosive dusts, such as TNT or PETN, are not to be tested in this laboratory.

APPENDIX B

PARTS LIST FOR CONTROL BOX

Schematic/Component	Description	Part no.
A1U1	Integrated circuit, dual monostable	MM74LS221J
A1U2	Integrated circuit, quad 2-in nor	CD14001BCN
A1U3	Integrated circuit, dual flip flop	CD14027BCN
A1U4	Integrated circuit, dual 3-in nor	CD14025BCN
A1U5-U7	Integrated circuit, counter	CD14029BCN
A1R1-R3	Resistor, fixed, 10K ohm, +/- 10%, 1/8 W	
A1R4	Resistor, fixed, 5.6K ohm, +/- 10%, 1/8 W	
A1R5	Resistor, variable, 10K ohm, +/- 10%, 1/8 W	
A1R6-R10	Resistor, fixed, 10K ohm, +/- 10%, 1/8 W	
A1R11	Resistor, fixed, 1.0K ohm, +/- 10%, 1/8 W	
A1R12-R23	Resistor, fixed, 10K ohm, +/- 10%, 1/8 W	
A1C1	Capacitor, 3.3 uF, +/- 20%, plastic	
A1C2	Capacitor, 2 - 47 nF, +/- 10%, metal polyester	
A1C3	Capacitor, 47 nF, +/- 10%, metal polyester	
A1C4-C5	Capacitor, 33 uF, +/- 20%, plastic	
A1D1	Diode, 1 A, 1000 V	1N4007
A1Q1	Mosfet, N-channel, 1.8 A	VN67AF
A1SW1	Toggle switch, SPST	
A2U8	Integrated circuit, decade counter/divider	MC14017B
A2U9	Integrated circuit, counter/display driver	ICM7217AIPI

A2R24	Resistor, fixed, 10K ohm, +/- 10%, 1/8 W	
A2R25	Resistor, fixed, 1.0K ohm, +/- 10%, 1/8 W	
A2R26	Resistor, fixed, 10K ohm, +/- 10%, 1/8 W	
A2D2-D5	Display, 7-segment, common cathode	LR-8322R
A2SW2,SW3	Switch, SPST, momentary, pushbutton	

A3R27	Resistor, fixed, 56K ohm, +/- 10%, 1/8 W	
A3C6	Capacitor, 2 - 10 nF, +/- 20%, ceramic	
A3C7	Capacitor, 3.3 mF, +/- 20%, electolytic	
A3C8,C9	Capacitor, 3.3 uF, +/- 20%, plastic	
A3D1A	Diode, 1 A, 1000 V	1N4007
A3T1	Transformer, low voltage, type C	166L14
A3L1	Relay, octal, DPDT	MK2EP-UA-DC12
A3F1	Fuse, 1 A	
A3SW4	Switch, SPST	
A3N1	Lamp, neon	NE2J
A3CR1	Bridge rectifier, 6A	MBA960-2
A3VR1	Voltage regulator, 12 V, 1.5 A	LM340T12
A3VR2	Voltage regulator, 5.0 V, 1.5 A	LM340T5.0